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## A RESTUDY OF THE 1917 ERUPTION OF VOLCÁN BOQUERÓN EL SALVADOR, CENTRAL AMERICA

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The 1917 eruption of Volcán Boquerón took place early in June of that year. The event was reported at that time in the local newspapers, *La Prensa* and *Diario Latino*. Later, it was described by Emanuel Friedlander (1918), Karl Sapper (1926, pp. 243-246), and others.

Unfortunately, none of these later authors saw the eruption. Friedlander was in Zürich, Switzerland, and he based his account partly on European newspaper reports and partly on official announcements that were made available to him by the Spanish Consul in Zürich, Señor M. De Soto. Sapper, who returned to El Salvador seven years after the eruption, states that most of the information he has used for his article was furnished by Edward Fischer, a naturalized Salvadorean, then residing at Santa Lucia, a coffee plantation (*finca*), some nine kilometers west of the city of San Salvador. Fischer was one of the eyewitnesses of the eruption. His account of the event has been most useful in compiling this account of one of the outstanding volcanic eruptions in Central America during the present century.

An attempt has been made here to verify the discrepancies of previous authors, especially with regard to time, date, and certain eruptive phenomena, and to reconstruct the event accordingly. I, too, was aided by my interview with Fischer, as was Sapper. The reports of Jorge Larde (1917) have also been most helpful. Purely descriptive material has largely been eliminated and certain salient features arising out of the eruption, which have not hitherto been dealt with and which I have observed in the field, have been noted. It would seem that certain aspects of the causes and effects of a given

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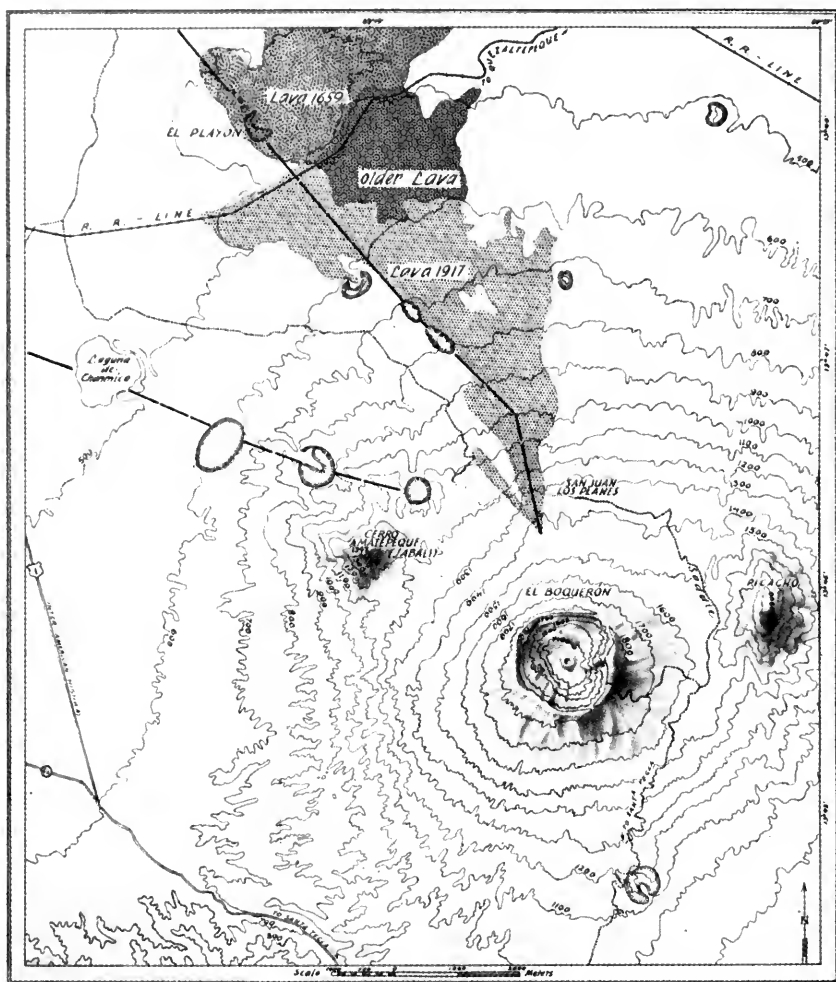


FIG. 143. Map of Volcán San Salvador group, showing distribution of the three units composing the group. Adapted from topographic map of Nueva San Salvador, El Salvador, Sheet 2357 III, AMS Series E 753.

eruption are more clearly understood and interpreted from the post-eruptive field studies than at the time of the eruption.

Boquerón (or Quezaltepeque) is the largest and the next highest (1,885 meters) of the three units of a group of volcanoes, collectively known as Volcán San Salvador. It is situated just west of the capital of El Salvador, which bears the same name as the volcán. Here it forms a conspicuous landmark and stands like a sentinel

guarding the metropolis. Ironically, it is this so-called sentinel that has been responsible for the repeated destruction of the city. Highly localized earthquakes, usually with volcanic accompaniments, have severely damaged or wrecked the city of San Salvador some thirteen times (1538, 1575, 1593, 1656, 1659, 1707, 1719, 1793, 1814, 1839, 1850, 1873, and 1917) since its founding.

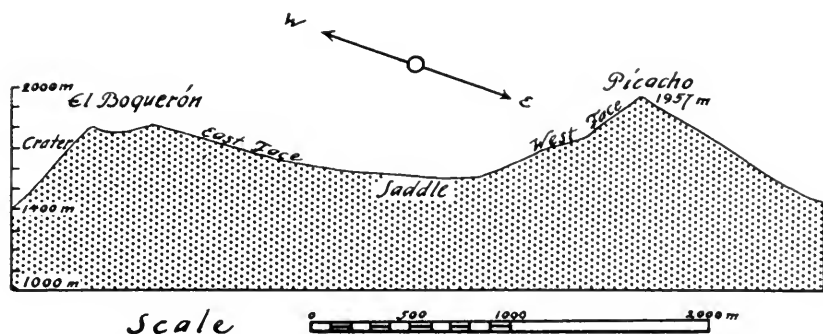


FIG. 144. Section through Boquerón and Picacho. The saddle is between the two.

The other two units of the group are Picacho (1,967 meters) and Amatepeque (1,397 meters); the latter is also called Jabalí. The distribution of these three units is shown on the sketch map (fig. 143). Picacho lies 3.3 km. northeast and Amatepeque 3.7 km. northwest of Boquerón. The east flank of Boquerón and the west flank of Picacho are separated by an elongated depression or saddle lying between 1,400–1,500 meters; a road, which begins at Santa Tecla (Nueva San Salvador) in the south and ends at San Juan in the north, winds through it (see figs. 143, 144). Sapper (1925, p. 51) mentions this saddle and states that it might be the remnants of a crater, but he dismisses the subject with the remark (trans.): "Only a prolonged investigation, for which I lacked time, could settle the question." The saddle does not have any of the earmarks of an old crater; it seems to be the natural lay of the land modified by gradational processes—a feature which is found in many volcanic areas between adjacent volcanoes. In most cases, saddles are broad areas of union between spurs extending laterally from opposite volcanoes or ranges of volcanoes. A striking example of this is Las Brumas between Volcán Santa Ana and Cerro Verde in El Salvador. The saddle between Boquerón and Picacho might well be the meeting place of the spurs of the two. Subsequent deepening and

widening by erosion, or filling in by deposits of ashes and pyroclastics probably has taken place, partially obliterating the original topography.

In contrast with the east face of Picacho, the west face is somewhat abruptly precipitous (fig. 145), unlike any natural development



FIG. 145. Volcáns Picacho and Boquerón, facing south. Note abruptly steep west face of Picacho.

of a volcanic cone; it suggests that this deviation from the normal was caused by a succession of violent explosions subsequent to the formation of the cone. The question naturally arises: What became of the thousands of cubic tons of materials that were shattered by the explosions? I have climbed to the summit of Picacho several times from different directions and have seen individual blocks of rocks on the slopes of the cone and around it but never in sufficient quantity to constitute the total mass lost. It may well be that, during the explosions, most of the rocks were broken into small fragments, which have since decomposed into soil.

On February 27, 1951, I made my first trip to the crater of Volcán Boquerón with Helmut Meyer-Abich, then a recently appointed Government Geologist of El Salvador, with offices at the Instituto Tropical. I wish to take the opportunity here to extend to him my sincere appreciation for his unfailing courtesy and friendly co-operation, both in the field and in the laboratory.

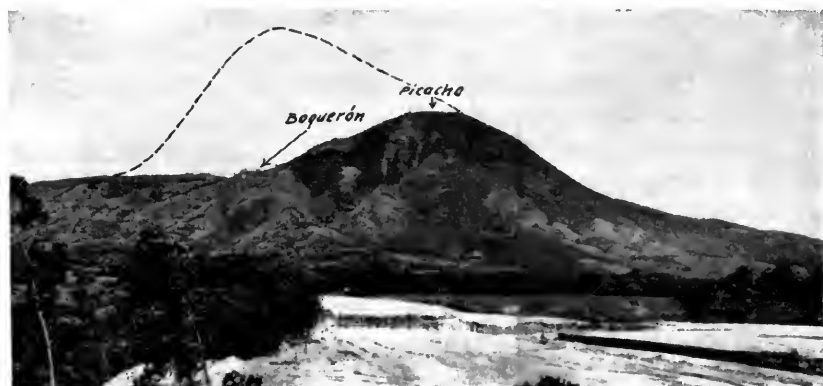
As we reached the summit of Boquerón the gigantic crater burst into our view. I had never before seen such a spectacular crater (fig. 146), and the suddenness of its appearance, the stillness per-



FIG. 146 (right). Crater of Boquerón, containing a small cone of vesicular lava with a crater of its own.



FIG. 147. Volcáns Picacho and Boquerón, facing east. The two might have been one volcano, as indicated by broken line.



vading the darkened hole with steep walls, some 550 meters deep, took me aback. An interesting feature of the crater is that it is nested, containing at the center of its floor another volcano, a small cone of vesicular lava with a crater of its own.

It was a cloudless afternoon and from the east rim of Boquerón I could clearly see the sheer west face of Picacho, the low saddle between the two volcanoes, and much of the surrounding landscape as far as Volcán San Vicente, some 60 km. away to the east. At first I thought that Boquerón and Picacho had been one volcano and that they had been connected in the manner shown in the photograph (fig. 147) and later separated by a rapid series of explosions. Field investigations that followed, however, bared no satisfactory evidence in support of this inference. On the contrary, it became more evident that Boquerón, Picacho, and Amatepeque came into existence separately.

Petrographically, the rocks of Boquerón and Picacho are not quite the same; the latter is more andesitic and it contains relatively more feldspar (80 per cent) and less pyroxene. With regard to the relative age of these volcanoes, it is well nigh impossible to reach a definite conclusion; neither their distribution nor their relationship to one another, so far as structural superposition is concerned, throws any light on the question. Dense growth of vegetation has added to the difficulty of making detailed structural studies of the basal portions of the volcanoes. Sapper (1925, p. 51) states that Boquerón is the younger but furnishes no proof of his statement. The fact that it has been periodically active since the latter part of the sixteenth century (the most recent activity being in 1917) is a good indication that it is younger and upholds Sapper's concept. In a group of volcanoes, the one that is active or has manifested periodic activity is likely to be the younger (Izalco in the Santa Ana group; San Miguel in the San Miguel group).

Meyer-Abich (1956) postulates a rather ingenious hypothesis<sup>1</sup> of the origin of Boquerón and offers it in support of his conception that Boquerón is the youngest member of the group. He states (trans.): "I have the impression that these peaks (i.e., Picacho and Jabalí) had formerly been independent volcanoes between which there stretched an oval basin, 5-6 km. in diameter. The Boquerón itself, that is, the central part of the mass, appears to be of more

<sup>1</sup> The hypothesis and the brief comment that follows were inserted after this paper had been completed.

recent age and to have been formed from the interior of the above-mentioned basin. Evidence supporting this hypothesis is found in a break in the north slope of the mass which runs from the north foot of Picacho (at about 1,300 meters altitude) westward in the form of an arc toward the west until it reaches to Jabalí. The course of this break can be followed more or less clearly. Above the break the slope of Boquerón (between 1,300 and 1,500 meters altitude) is 13 per cent ( $7.5^\circ$ ), whereas below the break the inclination of the slope of the old mass is about double ( $15^\circ$ )."

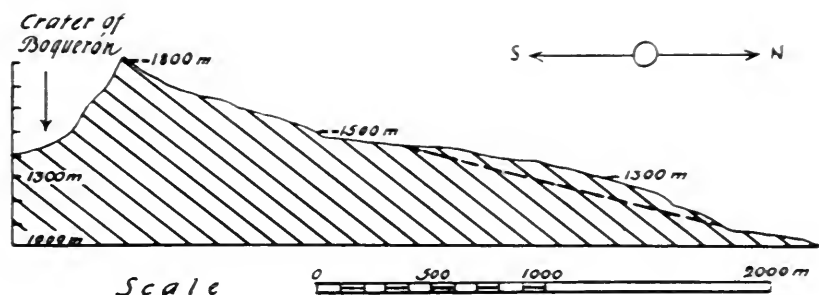


FIG. 148. Profile representing slope at  $89^\circ 17' 15''$  N. Lat. between  $13^\circ 46' 28''$  and  $13^\circ 44' 47''$  W. Long. Broken line shows original slope.

What is termed here a "break" occupies a very limited area, only a fraction of the total circumference of the base of the cone. The profile (fig. 148) representing the slope at  $89^\circ 17' 15''$  N. Lat. between  $13^\circ 46' 28''$  and  $13^\circ 44' 47''$  W. Long. (precisely above and below the "break" cited by Meyer-Abich) hardly offers a basis for assuming that there existed a basin at the present site of Boquerón. The change in the angle of the slope is not as abrupt as Meyer-Abich indicated. Moreover, such a change could result from unequal distribution of ejectamenta over a sloping surface that was originally gradual, or from superimposed lava flows that have stopped short of covering the entire slope. In fact, the course of the break may well be the continuation of the saddle, referred to earlier, which gradually terminates a little west of San Juan, and can not be construed as a mark of delimitation of a structural basin.

I have skirted the entire circumference of the rim of the crater of Boquerón (a distance of nearly 5 km.) at an average altitude of 1,800 meters. There are many vantage points from which many of the physical features of the volcano can be observed. The huge cone is steep and is dissected radially into deep gorges, more pro-

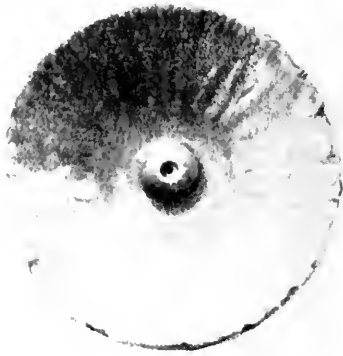


FIG. 149. A crater within a crater, the two having a common central vent.

FIG. 150. A nest of four craters. Eruptive vent has shifted.



nouncedly (to a mature topography) on the NE-SE side. It is also on this side that the rim of the crater has been damaged either by erosion or during past eruptions for a distance of about 1.2 km., thus interrupting the continuity of what was once a circular rim (fig. 143).

Except after heavy rains the crater is easily reached in a car equipped with four-wheel drive. The dirt road from Santa Tecla to San Juan (fig. 143) forks at an altitude of 1,500 meters on the east face of the volcano. The left branch of the fork then winds continuously uphill through several *fincas* to an open area at 1,800

meters, where it ends. From here a brick and cinder path climbs to a little "lookout" at the very edge of the crater. Narrow serpentine trails lead down the almost perpendicular walls to the floor of the crater, the center of which, as stated earlier, is occupied by a beautifully symmetrical cinder cone (locally called Boqueroncito) about 40 meters high, with a funnel-shaped crater. This cone was formed during the eruption of 1917, giving rise to a nested crater or a crater within a crater. Centrally placed nested craters have a common central eruptive vent (fig. 149) as is the case here; in the eccentrically placed craters, there is a shift in the position of the vent. In Volcán Santa Ana, which has four eccentrically placed craters, the eruptive center has moved at various times to the east (fig. 150) in the direction of Lake Coatepeque.

The descent and the ascent of the main crater of Boquerón, which is about 540 meters deep, take about two hours. Neither process is hazardous, although both are arduous. They should not be made after dusk, for the trails are narrow and rocky and in places run over ledges of sheer cliffs. The floor of the crater, which has an altitude of 1,347 meters, is covered with scoria ejected during and after the formative period of the Boqueroncito.

The rocks of Boquerón, whether older or newer, differ but little. All are basalt or basaltic andesite, composed chiefly of phenocrysts of basic plagioclase ( $Ab_4 An_6$ ) and varying amounts of pyroxene and augite; the groundmass is consistently hyalopilitic.

When I first visited the crater, there was a placard (since removed), giving pertinent information in English and Spanish about the 1917 eruption (fig. 151). Obviously intended for visitors, it was posted prominently just outside the "lookout," on a bit of level ground within a few feet of the eastern rim of the crater. It read:

#### DATA CONCERNING SAN SALVADOR OR QUEZALTEPEC VOLCANO

##### *Geographic Position:*

Crater  $13^{\circ} 43' 55''$  N. Lat. and  $89^{\circ} 17' 20''$  W. Long. Greenwich. Height above sea level: 1,887 m. Diameter of crater:  $1\frac{1}{2}$  ks. Circumference: 4,712 m., approximately 5 ks. Depth of crater: approximately 500 m.

##### *Lake in the Interior:*

In the past there was a lake at the bottom of the crater 400 m. in diameter, the water of which evaporated as a result of the eruption that took place on the 7th June 1917.

##### *Eruption in 1917:*

On Corpus Christi Thursday, 7th June, 1917, at six o'clock in the afternoon, a series of violent earthquakes were the beginning of an eruption of the volcano



FIG. 151. Placard (now removed) posted at rim of Boquerón crater, giving information in English and Spanish about 1917 eruption.

which burst out on the NW slope ejecting a huge current of lava together with dense clouds of gas and fumes. Little craters remaining on that side of the volcano are called craterlets (boquerónicos). The eruption took place in the evening at 8:00 o'clock.

#### *Eruption at the Big Crater:*

Three days after the eruption took place the lake at the bottom commenced to boil, forming dense clouds of vapor. By the end of June the lake had evaporated completely and formidable explosions followed from a cleft that appeared at the bottom of the crater, gas and ashes being thrown up in tall columns every five or ten minutes through the cleft. These explosions continued at intervals

each greater in length until the first days of November of the same year. The cone at the bottom of the crater was formed by the ashes and hardened by the rains. THE COMMITTEE FOR THE BEAUTIFICATION OF ROADS, SUBURBAN AREAS, PATHS AND PUBLIC PARKS.

The above contents conform essentially to those cited in the literature of the event. There are a few discrepancies, most important of which is that the earthquake that heralded the eruption took place on Wednesday, June 6, at 6:55 P.M., not on Corpus Christi Day.



FIG. 152. City of San Salvador, showing damage caused by earthquakes that accompanied 1917 eruption.

According to Mr. Fischer, now Director of the Zoological Garden at San Salvador, the second shock caused the most damage to the settlements surrounding Boquerón, including the city of San Salvador (fig. 152). The photographs illustrating the evaporation of the crater lake (figs. 153–158) were made by Mr. Fischer. I am very thankful to him for giving me permission to reproduce them and for furnishing me vital statistics of the memorable eruption.

Following the second shock (June 6, about 7:10 P.M.), a fissure burst out on the northwest side of Boquerón, along which sprang up a series of craterlets (fig. 163). From these poured out streams of lava that flowed fanwise in the direction of Sitio del Niño. The rapidly advancing lava soon engulfed a large territory, went past the Quezaltepeque–Ciudad Arce railroad line (fig. 160) and abutted against the older lava fields, one of which resulted from the eruption



FIG. 153. Lake in crater of Boquerón before 1917 eruption.

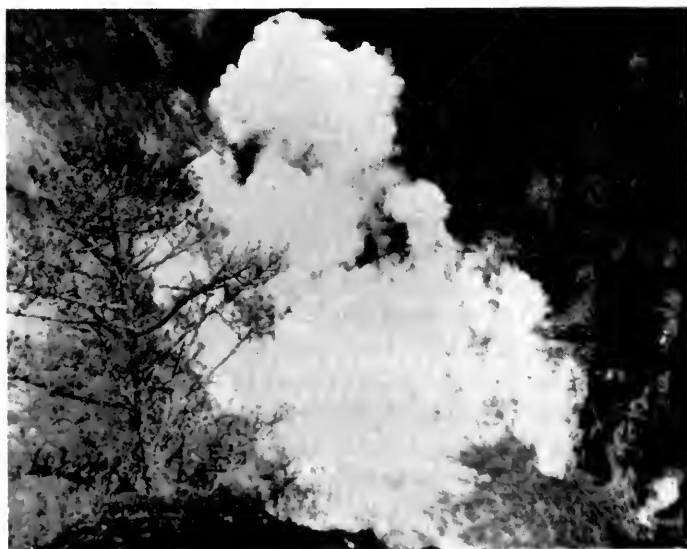


FIG. 154. Evaporation of crater lake.



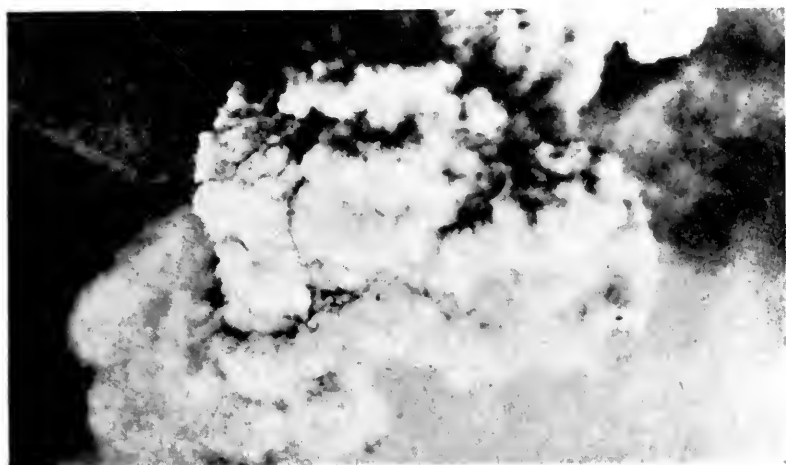


FIG. 155. Emergence of a cone (Boquerónico).



FIG. 156. Beginning of an eruption of Boquerónico.



FIG. 157. Eruptive activity of Boqueroncito.

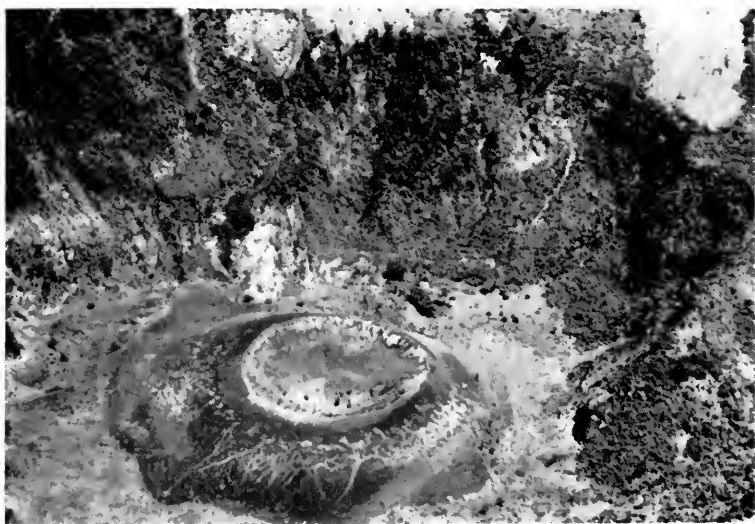


FIG. 158. Boqueroncito after eruption.



FIG. 159. Bottom of crater of Boqueróncito, 35 meters deep.



FIG. 160. Lava on Quezaltepeque-Ciudad Arce railroad line some 6 km. north from seat of eruption.



FIG. 161. Craterlets, many of which have coalesced, giving off steam and other gases, and exploding intermittently.

of 1659. On or about June 11, barely five days after the eruption had begun, the lava ceased to flow, but the craterlets, some of which have already coalesced, remained active until the middle of June (fig. 161). By this time the typically *aa* lava had covered an area of nearly 16 square kilometers and had built up a jagged terrain, much of which is today without vegetation and difficult to walk over. Fumarolic activity is still in progress in two of the craterlets situated at the southernmost tip of the fissure. At the beginning, the more active craterlets were formed between 1,350 and 1,400 meters; one located farther down the slope at an elevation between 650 and 580 meters was the most violently active. Besides pouring out lava in profusion, it manifested the Strombolian type of eruption, exploding frequently with deafening reports like claps of thunder. J. Larde named it *El Tornador* (the Thunderer, fig. 162; Larde, 1917). Strong but highly localized earthquakes also accompanied the eruptions of this craterlet.

It may be brought to attention here that west of this 1917 fissure and its craterlets, and bordering the northeast side of Volcán Jabalí, there is an older radial fissure with similar craterlets (fig. 143). These two fissures, which are approximately of the same length, about 8 kilometers, run parallel, and their craterlets, which occupy about the same elevations, face one another. The fact that they are so arranged may be accidental, but their presence along the



FIG. 162. El Tornado (The Thunderer), one of the most active of the craterlets.

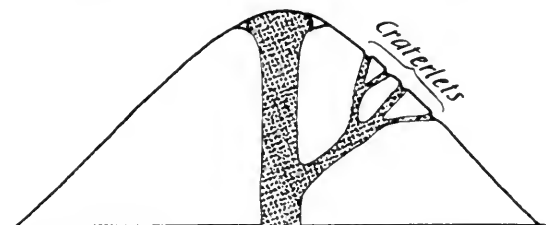


FIG. 163. Schematic diagram showing origin of craterlets along flank fissure.

respective fissures bears evidence to the fact that craterlets are of common occurrence along flank fissures. They owe their origin to diagonal feeder pipes (fig. 163). The pipes are secondary cracks (offshoots) formed during the initial eruption and later enlarged by explosive activity. Absence of craterlets indicates that the explosive activity through the diagonal pipes has been at a minimum; lava simply has risen through them, pushed aside the overlying partially congealed materials and rolled down the slope. This phenomenon was observed at night during the 1955 eruption of Volcán Izalco, El Salvador.

Prior to the eruption, there existed a lake (fig. 153) in the crater of Boquerón (Sapper, 1925). It occupied an eccentric position with a surface level at an elevation of about 1,420 meters above sea level,

which would indicate that it was  $80 \pm$  meters deep. That the lake level was once higher is evidenced by the remnants of a terrace on the northeast side of the crater at an altitude of 1,670 meters. The dimensions of the lake as estimated in 1895 by Sapper (1925, p. 51) were: N-S, 400 meters; E-W, 350 meters.

The water of the lake was apparently not potable; it was covered with water-bloom composed of green algae and had an obnoxious odor. An analysis by J. Puente (Sapper, 1925, p. 51) showed that in addition to organic matter it contained sulphates and carbonates of calcium and magnesium. The potability of the water is brought to attention here purposely. Despite the difficulty of getting in and out of the crater and the long and exhaustive trek to Santa Tecla, the nearest trading town, there is a handful of men and women who actually live in the crater proper the year around. Perhaps the populace was greater when the lake existed. Since no water is to be found anywhere within miles except during the rainy season (June–October), these people must perforce use the lake water. They eke out an existence inside the crater by raising flowers—various species of *Hydrangea*, *Lilium*, *Geranium*, *Aster*, and *Dianthus*. These are grown on the slopes and ledges where the rocks have decomposed to soil, which, like all volcanic soil, is remarkably fertile. The making of charcoal from the vegetation in and around the crater is another source of living. El Salvador has no natural fuel such as oil or coal, in consequence of which the country has been so denuded of first-growth trees that wood must be sought even in the mouths of volcanoes.

On June 9–10, when the fissure eruption was still in progress but waning, the lake began to boil, emitting clouds of vapor that all but obscured the view of the crater (fig. 154). At intervals, steam clouds rose at both ends of the lake, during which the lake level was seen to undulate. Evidently, intermittent eruptions at the bottom of the lake were taking place. The boiling continued until June 28, when the water had completely evaporated. Assuming that the lake was ellipsoid and the basin more conical than rounded and 80 meters deep it contained some three million cubic meters of water. The total heat required for the vaporization of this volume of water under atmospheric pressure at an altitude of 1,420 meters above sea level would be approximately  $73.17 \times 10^{11}$  BTU's.

Concurrent with the evaporation of the lake, a cleft on the dry floor was observed, through which, at the beginning, spurted mud and clots of lava accompanied by steam and other gases (fig. 155).

Soon this changed to a full scale eruption; up came bombs, lapilli, and other ejectamenta. One explosion followed another at intervals of 5 or 10 minutes and columns of incandescent lava and gases shot high into the air, almost to the rim of the main crater. Out of this spectacular display there emerged at the center of the old crater a perfectly shaped cone (Boqueroncito) of vesicular lava and ashes with a funnel-shaped crater (about 35 meters deep) that could be clearly seen between eruptions (figs. 158, 159). Thus formed a cone within a cone, the two having a common central vent. In eight days, between June 28 and July 5, the cone rose to a height of about 40 meters. Curiously, in spite of the fact that the eruptions from the newly formed volcano continued until November of the same year, including heavy ash eruptions during July, August, and September, the height of the cone remained practically unchanged. Apparently, the ejectamenta fell far and wide; little or none was left on the cone itself for its growth and development. It could be inferred that the crater eruption would have been far greater, perhaps disastrous, had not the flank eruption preceded it. Much of the stored energy and materials and the attending explosive was released before reaching the main crater.

In places, the rocks of the little crater are still lukewarm. They show little or no signs of weathering outwardly or in the interior. The dominant minerals—olivine, feldspar (labradorite) and augite—as seen in thin sections, appear quite fresh. Yet wisps of grass, *Andropogon rufa* (Nees) Stapf, the widely distributed tropical clubmoss, *Lycopodium cernuum* L., and the blue-green alga, *Pityrogramma calomelanos* (L.) Link, were observed to grow sparingly both on the slopes of the cone and on the sides of the crater. Another species of grass, *Hyparrhenia rufa* (Nees) Stapf, closely related to the turkey-foot that covers the drier places in prairies and sand-plains of our northern states, was relatively abundant on the floor of the main crater.

At the present time, there is no activity of any kind in the Boqueroncito. A single fumarole, feebly emitting steam and sulphurous gas, was observed on the northwest wall of the main crater.

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